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MACHINE CRUSHED COW BONES AS A PARTIAL REPLACEMENT OF FINE AGGREGATES IN LIGHTWEIGHT CONCRETE

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ABSTRACT

A study on the suitability and effectiveness of machine crushed cow bones (MCCB) as partial replacement of fine aggregates in concrete works was carried out. Mechanical and physical properties of machine crushed cow bones as a partial replacement for locally available fine aggregates have been determined and compared. 36 concrete cubes of 1:2:4 mix design ratio measuring 150x150x150mm with varying percentages by weight of normal concrete aggregates to crushed cow bones as fine aggregate in the order 100:0, 75:25, 65:35, 50:50, 25:75 and 0:100 were cast, cured and tested after 14, 21 and 28 days and their physical and mechanical properties were determined. Compressive strength tests showed that at 25:75 (MCCB:Sand) ratio at 28 days, a strength of 17.6 N/mm^2 was achieved at 1:2:4 concrete mi ratio. At 50: 50 (MCCB:Sand) ratio, the compressive strength obtained after 28 days was 16.5 N/mm^2. The study has been carried out at 25%, 50%, 65%, 75% and 100% replacement levels of fine aggregate by machine crushed cow bones (MCCB) aggregate by weight and a comparative analysis of the result has been carried out between normal fine aggregate and machine crushed cow bone concrete. The values of the compressive strength at 28 days for replacement levels of (25% - 50%) fine aggregate by MCCB corresponds to values of compressive strength for lightweight concrete (17.6 N/mm^2 - 16.5 N/mm^2). Aggregate Crushing Value (ACV) for MCCB is 32% and that for fine sand is 17.89%, while Aggregate Impact Values (AIV) for the CCS is 1.22% and that for river san is 11.8%.

Keywords: machine crushed cow bones, fine aggregate, compressive strength, concrete, workability, slump values.

1. INTRODUCTION

Concrete is a massive and weighty construction material used commonly in Civil Engineering construction worldwide. Different varieties of lightweight concrete are being manufactured currently.

In earlier years, the Romans established the durability of lightweight concrete by using natural aggregates from volcanic deposits. After the development of Portland cement in the early 1800s, it took the discovery and development of manufactured lightweight aggregates in the early 1990s to bring structural lightweight concrete to full maturity. The main natural lightweight aggregates are diatomite, pumice, volcanic cinders [17].

The primary aim of lightweight concrete is to reduce the dead weight of concrete to be used in a structure which then allows a designer to reduce the size of structural elements (columns/beams) and size of foundation as well [14].

Many research works have been carried out in recent years using waste materials to produce lightweight concrete.

[1, 18, 12, 2, 15, 21] have carried out exploratory studies on the use of palm kernel shells as lightweight aggregate to produce lightweight aggregate concrete.

[23] has also investigated the use of volcanic slag as coarse aggregate in the production of semi-lightweight concrete.

[24] also used a combination of coconut shell and grained palm kernel shell as lightweight aggregate in concrete production.

[19] carried out an exploratory study of crushed periwinkle shell as partial replacement for fine aggregates in lightweight concrete.

[14] undertook an exploratory study on the suitability of machine crushed animal bones as partial or full replacement for coarse aggregates in lightweight concrete.

The study being here-in presented, is the use of machined crushed cow bones as partial replacement for fine aggregates in lightweight concrete.

Cow bones constitute a big nuisance in abattoirs all over the world where cattle are slaughtered for human consumption. Heaps of cow bones are usually worm infested and are smelly where ever they are dumped.

Various researches aiming to produce lightweight concrete from manufactured or aggregates from individual or agricultural by-products, is gradually becoming very popular. This is due to the fact that industrial and agricultural wastes are being re-used thereby ensuring that environmental degradation arising from the production of these waste products are curtailed to the barest minimum.

METHOD

Materials

The following materials were used for the experiment:

Cow bone was collected from an abattoir at Agip Mgbuoshimini Market in Port Harcourt, Rivers State of Nigeria.

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Cement: Ordinary Portland Cement (OPC) locally available in Nigeria (the DANGOTE CEMENT Brand Name) in 50kg bags was used for the experiment.

Water: Potable water from the Civil Engineering Laboratory of the Rivers State University of Science and Technology was used to prepare the moulds and cubes as well as washing of the dirty periwinkle shells..

Coarse aggregate (Gravel): Crushed granite stones was obtained from Crushed Rock Industries quarry in Ishi-Agu, Ebonyi State, Nigeria.

Method

The cow bones (CB) were washed clean and dried in the open air to clean out the dirt and to reduce the moisture content. The CB were first of all broken down to smaller pieces with a big mallet The smaller pieces of CB were then crushed with a machine to produce fine aggregate shapes designated as Machine Crushed Cow Bone (MCCB) fine aggregate.

These MCCB fine aggregates were used as partial to full replacement of conventional fine aggregates in concrete cube specimens.

Concrete mix ratio of 1:2:4 with a water/cement ratio of 0.60 and 0.75 respectively has been used in the study. Ordinary Portland Cement (OPC) Grade 42.5, conforming to BS 12; 1996, natural river sand (fine aggregate), crushed cow bone and coarse aggregate are other civil engineering materials used in the production of concrete specimen for the study.

MCCB/River Sand combination as fine aggregate (in percent weight) in the following proportions 0:100, 25:75, 50:50, 65:35, 75:25, 100:0 in the preparation of the concrete cubes Thus the replacement of the normal fine aggregate by MCCB is in the range of 0% to 100%.

The first three sets MCCB: River Sand (0 - 50% MCCB) proportion was prepared with a mix ratio of 1:2:4 and water /cement ratio of 0.6, while the last three sets MCCB: River Sand (65-100%) was prepared with a mix ratio of 1:2:4 and water cement ratio of 0.75.

The following tests were carried out for aggregates: specific gravity, bulk density, sieve analysis, Aggregate Crushing Value and Aggregate Impact Value.

For the MCCB: river sand concrete mix, the following tests were carried out: slump test, setting time and compressive strength.

Table-7: Test methods used for measuring aggregate and concrete properties

Result/analysis of tests

The MCCB fine aggregate had sizes in the range of .0.07mm - 2.5mm. The MCCB (fine aggregate) were used as partial to full replacement of conventional fine aggregates in concrete specimen.

Properties of machine crushed animal bone (MCCB)

Table-1 shows the physical properties of the MCCB and those of normal fine aggregate. Physical properties listed are: maximum aggregate size, Bulk Density, Specific Gravity, Aggregate Crushing Value (ACV), Aggregate Impact Value (AIV), Coefficient of Uniformity and Coefficient of Curvature.

Figure-1 shows the particle size distribution for the MCCB, sand and gravel used for the study.

Table-2 shows the mechanical properties of bones [16].

Figure-2 is a typical stress-strain curve resulting from a tensile test conducted on a bone specimen for reference purposes [16].

Observation of Table-1 reveals that the crushing value of (MCCB) fine aggregate is higher than normal aggregate which indicates the poor strength quality of MCCB when compared to normal fine aggregate.

From Table-1 it is shown that the Bulk Density of MCCB is 1022 kg/m^3 and this is approximately 39% lighter than normal conventional fine aggregates (1670/kg/m^3.).

Specific gravity

Table-1 show that the Specific Gravity of MCCB is lower than that of fine aggregate (river sand). This is expected as a result of the fact that the grains of MCCB are larger than those of the river sand.

Coefficient of uniformity

Values of coefficient of uniformity indicates that the MCCB (3.8) and river sand (2.87) is well graded.

Coefficient of curvature

Values of coefficient of curvature of MCCB (0.86) are lower than that of the river sand (1.23).

Moisture Content

Moisture Content of the MCCB (6.8%) is expectedly higher than that of the river sand (3.48%) (fine aggregate).

Properties of light weight concrete with machine crushed animal bone (MCCB) compressive strength

The compressive strength of concrete cubes made with partial or full replacement with MCCB has been determined after 14, 21 and 28 days. The result is shown in Table-3. Figure-3 shows a plot of the compressive strength versus the proportions of MCCB replacement in the concrete cube at 14, 21 and 28 days. Generally it is observed from Table-3 and Figure-3 that the compressive strength decreases as the percentage of MCCB increases. The compressive strength has a maximum value for the control value (0% MCCB) fine aggregate and minimum for the (100% MCCB) fine aggregate content.

However, it was observed that the compressive strength of the concrete cubes with 25:75 (MCCB: River Sand) at 1:2:4 mix ratio and 0.6 water cement ratio at 21 and 28 days are 16.95 N/mm^2 and 17.6 N/mm^2 respectively. These values compare favourably with compressive strength for lightweight concrete which in some codes of practice are defined as concrete with a

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minimum strength of 15.0 N/mm^2 [13]. The values of the ACV and AIV in Table-1 supports the appreciable values of the compressive strengths obtained at 25:75 (MCCB: River Sand). The MCCB is neither an exceptionally strong aggregate nor a weak aggregate. ACV values of less than 10 are regarded as exceptionally strong aggregates and values of ACV above 35 are regarded as weak aggregates.

Workability

Table-4 shows the results of the slump test for the various percentages replacement of MCCB with river Sand, while Figure-4 shows the plot of the slump values against the percentage replacement of river Sand with MCCB. The slump value decreases from 35mm at 0:100 (MCCB: River Sand) to 9mm at 65:35 (MCCB: River Sand). Thereafter, it rises to a value of 16mm at 100:0 (MCCB: River Sand). The reduction in workability as the percentage of MCCB increases can be attributed to the fact that since the normal fine aggregates are denser (heavier) than MCCB agggreagates and replacement is by weight, the specific surface area increases as the MCCB aggregate content is increased. However, since the MCCB aggregates are very light and do not settle (sink) easily, slump test is not a true indicator of workability for MCCB concrete [14]. The value of workability obtained offers a fair assessment of the MMCB on workability of MCCB: River Sand concrete.

Unit weight

In structural applications of lightweight concrete, the density is far more important than the strength, (Rossignolo *et al*., 2003). Table-5 shows the values of the unit weight for the various percentages of the MCCB: River Sand at 14, 21 and 28 days for 1:2:4 mix ratio and water cement ratios of 06 and 0.75 respectively. Figure-5 is the plot of the values in Table-5.

As can be observed from Table-5 and Figure-5, there is a reduction in unit weights as the MCCB fine aggregates increases.

Observation of Table-5 shows that the average unit weights corresponding to 25%, 50%, 65% , 75% and 100% of MCCB fine aggregate inclusion in the concrete are 2490 kg/m^3, 2330 kg/m^3, 2330kg/m^3, 2180kg/m^3 and 2090kg/m^3 at 28 days, respectively for the 1:2:4 mix. These values compares favourably with the values of unit weight for light weight concrete which are defined as concrete whose dry density is in the range of 1427 $kg//m^3$ to 2040 kg/m^3., compared with that for normal-weight concrete [11].

Retardation

As shown in Table-4 and Figure-6, the setting time of the concrete increased with increase in the percentage of MCCB in the concrete. The setting time of the concrete (w/c=0.6) with 0% MCCB was 45 minutes, while the setting time of the concrete (w/c=0.75) with 100% MCCB was 4 hrs.

Particle size distribution for aggregates

Figure-1 shows the particle size distribution curve for the MCCB, river sand and gravel.

Chemical properties of cow bone

Table-6 shows the chemical properties of cow bone used for the study. Calcium and Silicon constitute more than 60% of the total constituent of the cow bone. The calcium content accounts for the reduction in compressive strength, while the silicon content is responsible for the nearness of the properties of the MCCB to that of river sand.

4. CONCLUSIONS

The following conclusions were deduced from the analysis of the result of the study.

a) Lightweight concrete using MCCB as fine aggregate can be easily achieved by replacing normal fine aggregate with MCCB to a maximum of 50% replacement.
b) Values of compressive strength of MCCB (fine aggregates) lightweight concrete is comparable to values of compressive strength of normal fine aggregate up to 50% replacement with MCCB, thereafter, the compressive strength of (MCCB) fine aggregate reduces to very low values.
c) MCCB (fine aggregate) in concrete reduces the workability of concrete.
d) MCCB acts as a retarder in concrete works.
e) MCCB helps to achieve economy of construction by reducing the unit weight of the structure [14].

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5. APPENDICES

5.1. Tables

Table-1. Physical properties of aggregates.

Properties	MCCB fine aggregate	Normal fine aggregate
Maximum Aggregate size(mm)	5.0	5.0
Bulk Density (Kg/m^3)	1022	1670
Specific Gravity (SSD), Kg/m^3	1.42	1.92
Aggregate Crushing value (%) ACV	32	17.89
Aggregate Impact value (%) (AIV)	27.7	11.83
Coefficient of uniformity (C_u)	3.8	2.87
Coefficient of curvature (C_c)	0.86	1.23
Moisture Content (%)	6.48	3.48

Table-2. An Overview (or representative average) of cortical bone properties for human and cow, Martin *et al*; (1988).

Property	**Cow** (Borine) **value**
Elastic Modulus transverse	20.4 GPa
Elastic modules long	11.7 Gpa
Shear modules	4.1 Gpa
Tensile yield stress long	141 MPa
Tensile ultimate stress long	145 MPa
Tensile ultimate stress transverse	50 MPa
Compressive yield stress long	196 MPa
Compressive yield stress transverse	150 MPa
Compressive ultimate stress long	137 MPa
Compressive ultimate stress transverse	178 MPa
Tensile ultimate strain	0.67 - 0.72%
Compressive ultimate strain	2.5 - 5.2%

Table-3. Average compressive strength of concrete at 14, 21, and 28 days for 1:2: 4 mix ratio.

w/c ratio	% of MCCB in concrete	% of sand in concrete	**Compressive strength** (N/mm^2)		
			14 days	**21 days**	**28 days**
0.6	0	100	18.3	19.5	23.55
0.6	25	75	7.75	16.95	17.60
0.6	50	50	9.35	9.35	16.50
0.75	65	35	5.50	6.05	6.50
0.75	75	25	5.10	5.05	5.85
0.75	100	0	3.09	4.00	4.20

Table-4. Slump test results.

% of MCCB	% of sand	w/c ratio	Slump (mm)	Category	Workability	Setting time
0	100	0.6	36.5	True	Low	45 mins
25	75	0.6	29	True	Low	1 hr
50	50	0.6	12	True	Low	1 hr
65	35	0.75	9	True	Low	$2^1/_2$ hrs
75	25	0.75	10	True	Low	3hrs
100	0	0.75	6	True	Low	4 hrs

Table-5. Variation in unit weight of hardened concrete at 14, 21 and 28 days for 1: 2: 4 mix ratio.

% of MCCB	% of sand	w/c ratio	**Density** (unit weight) (Kg/m^3)		
			14 days	**21 days**	**28 days**
0	100	0.6	2410	2620	2790
25	75	0.6	2370	2520	2490
50	50	0.6	2150	2280	2330
65	35	0.75	2020	2240	2330
75	25	0.75	2100	2160	2180
100	0	0.75	1810	2060	2190

Table-6. Chemical analysis of cow bone.

Parameter	Test method	Result	Standard
pH	ASTMD 51-77	5.76	>5
Specific Gravity	ASTMD 58	2.41	2.2 - 2.6
Carbonate (%)	BS 3921	0.93	1
Silicon (%)	BS 1377	13.8	20
Iron (%)	ASTMD 632	0.23	0.5
Salinity (%)	BS 1377	0.44	1
Aluminum Oxide (%)	BS 1377	0.017	0.05
Sulphure (%)	BS 1377	1.51	2.0
Magnesium (%)	BS 1377	0.28	0.5
Calcium (%)	BS 1377	50.70	70
Phosphate (%)	BS 1377	0.29	0.5
Potassium (%)	BS 1377	0.043	0.05

Table-7. Test methods used for measuring aggregate and concrete properties

Properties	Test method
Specific gravity	BS 1377 : part 3: 1990
Sieve analysis	BS 410 : 1986
Aggregate crush	BS 812 Part 110: 1990 Bs 812 part 112: 995
Impact value of slump	BS 1881 : part 102: 1983
Compressive strength	Bs 1881: part : 114:1983

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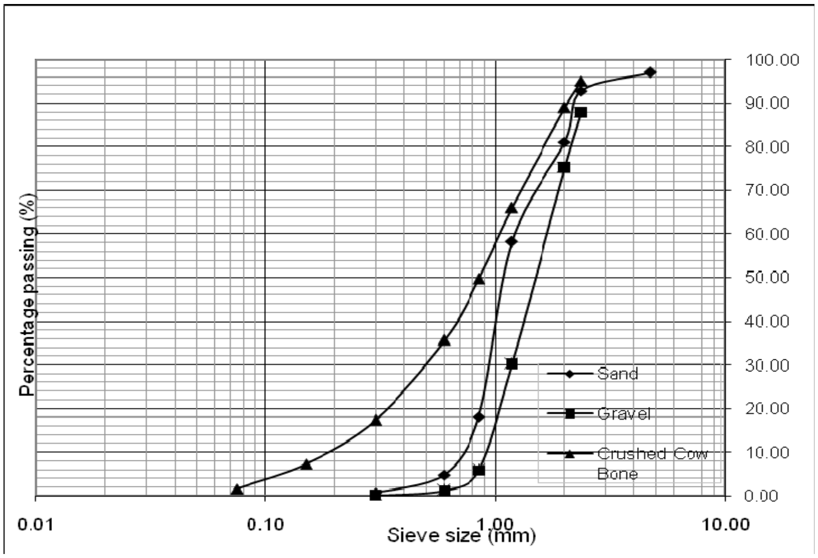

Figure-1. Particle size distribution curve for aggregates.

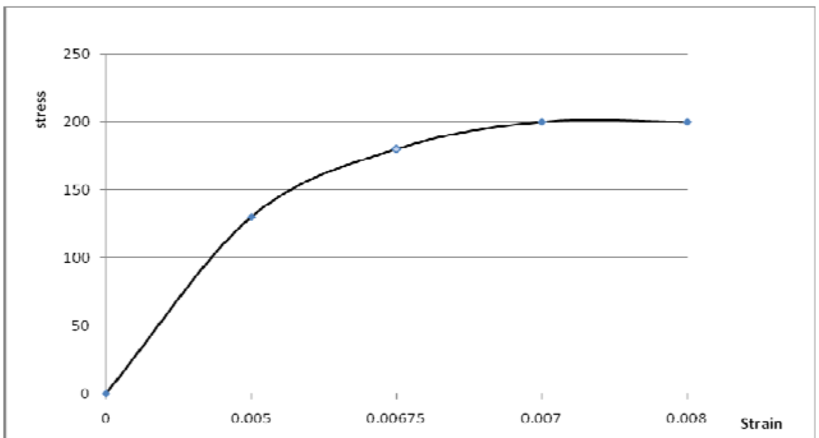

Fig. 2: Illustration of a bone test specimen and a stress strain curve resulting from a tensile test (Martin et al, 1998)

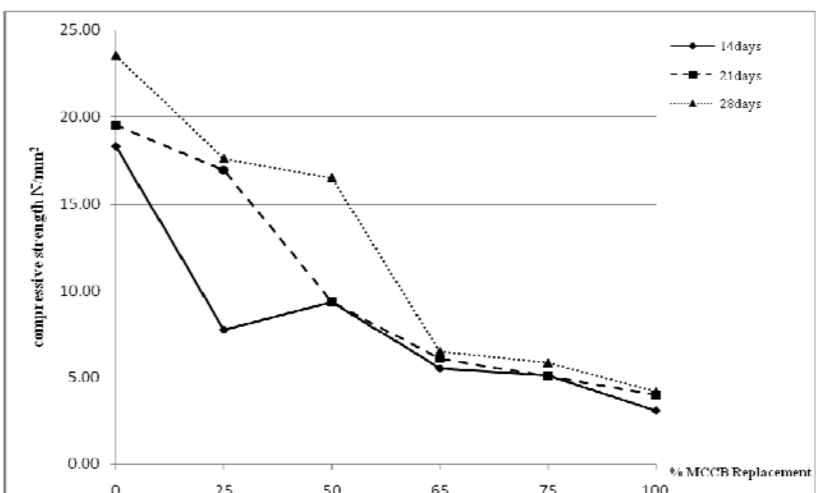

Fig. 3: Variation of Compressive strength with Replacement of sand by MCCB

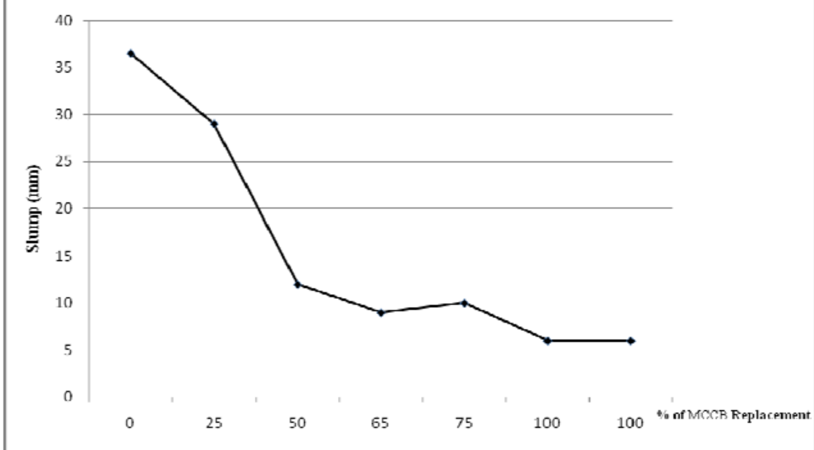

Fig. 4: Slump test Result curve

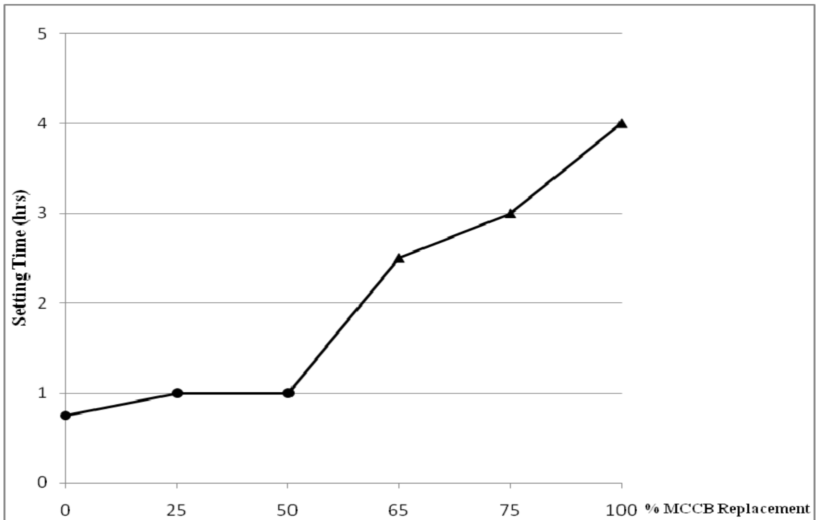

Fig. 6: Plot setting Time against % MCCB Replacement for 0.6 w/c and 0.75 w/c

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